LETTERS TO THE EDITOR

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On the Origin of Flagellate Monads and of Fungus-germs from Minute Masses of Zooglœa.

BACTERIAL scums are exceedingly common in ditches and ponds, nature's laboratories, and it is a matter of much importance to know what goes on therein. Some light may be thrown upon this subject by making infusions or macerations from cut fragments of various plants, and then examining, at different periods, the scum or pellicle that forms on such fluids. What I have now to say will refer almost exclusively to infusions made from hay. The hay employed may be either fresh or old, but it does not do to substitute for hay mere unripe grasses. I have elsewhere shown how remarkably different are the products derivable from living unripe grasses and from ordinary hay.[1]

In making such an infusion I have been accustomed to cut the hay into short pieces, to place these in a little beaker, and then to add water so as well to cover the fragments. After maceration for three or four hours at a temperature of about 86° F. (30° C.), the infusion has been filtered through two or three layers of the finest Swedish filtering paper into another small beaker. In this way all but the smallest particles, 1/12,000 of an inch or thereabout, will be excluded. For observation of the changes now to be described it is best that the bacterial scum, which soon forms on the surface of the fluid, should be very thin, therefore the depth of the fluid ought not to be more than about one and a half inches—though if one is seeking to make out the origin of ciliated Infusoria infusions of greater depth should be employed in order that a fairly thick pellicle may form.

When such an infusion is kept under a bell-jar (to exclude dust) at a temperature of about 65° F. (18° C.), the pale sherry-coloured fluid in less than twenty-four hours becomes lighter in colour and very turbid. Soon a scum, almost invisible, begins to form on the surface, composed of several different kinds of bacteria, and in about thirty-six hours small Zooglœa masses of the most varied sizes and shapes begin to appear therein. In Fig. 1, A, a portion of such a scum is shown as it appeared at the end of the third day on a hay infusion in which the masses of Zooglœa were exceptionally numerous. The portion of this scum here represented had been transferred on the tip of a sterilised scalpel to a drop of a dilute solution of eosin, which stained the surrounding bacteria a pale red tint, but left the Zooglœa masses unstained, so that they were rendered very distinct. Had logwood been used the results would have been reversed—that is, the Zooglœa areas would have been more or less deeply stained, while the surrounding bacteria would have remained unstained.

Examination of one of these masses with a high power will show its constitution, and reveal the fact that we have to do with an aggregation of separate bacteria imbedded in a jelly-like material. This may be seen from Fig. 1, B, which shows a highly magnified portion of one of the Zooglœa masses from the same pellicle after it had been immersed in a drop of a weak solution of Ehrlich's eosinophyle fluid, which stained the surrounding bacteria a yellow tint, while it left the Zooglœa mass unstained. The slightly altered bacteria within the Zooglœa mass are at this early stage plainly to be seen, though later on they become more or less obscured by reason of progressive molecular changes taking place in the mass during its subsequent transformation.

Some of these Zooglœa masses are destined ultimately to be converted into numbers of flagellate Monads or of Amœbæ, while others become resolved into heaps of Fungus-germs. I have found it impossible to tell from the mere microscopical appearance of the Zooglœa masses whether they are destined ultimately to yield Monads or Fungus-germs. The latter transformation is undoubtedly by far the commoner of the two, and when I was working for many months at this subject during 1899 I was unable to find any good specimens, capable of being photographed, showing the conversion of Zooglœa masses into Monads, although I many times saw and photographed Monads originating from the pellicle as discrete motionless corpuscles—especially when the infusions were kept at a temperature of about 72° F. (22° C.).[1] But one day last month, on October 19, desiring to make certain observations, I made a weak infusion from a portion of a small handful of hay gathered in Norway more than two months previously, which had since been kept in a small cardboard box. The infusion was prepared and filtered in the manner already indicated, and divided into two portions: one, which we may name A, being placed in a small open beaker and left beneath a bell-jar at the end of the mantelpiece in my study; while the other (a very small portion), which we may name B, was put into a small half-ounce earthenware pot, over which the cover was placed. The two specimens of the infusion, covered and uncovered, were then left side by side beneath the bell-jar, so that the temperature to which they were exposed might be as nearly as possible similar. Some of the changes in the scums that formed on the surface of these fluids are now to be described.

Origin of Flagellate Monads from Minute Masses of Zoogloea.

A. When examined fifty-one hours after the time of filtration the scum on this infusion was found to be very thickly crowded with small masses of Zooglœa varying much in shape and actual size, as shown in Fig. 1, A.

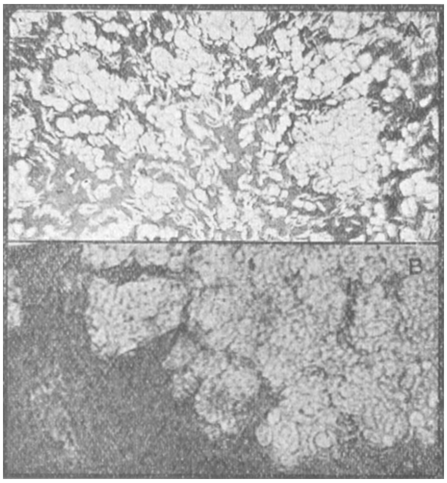

FIG. 1.—A, Zooglœa masses in the scum on a hay infusion (× 100); B A portion of one of these masses showing the contained bacteria (× 500)

In the course of the fourth day very many of the smallest masses were seen to be undergoing segmentation into small motionless spherical bodies, while multitudes of active flagellate Monads of the same size were for the first time seen in the fluid and in the midst of the portion of the scum under examination. When a similar examination had been made twelve hours previously not a single Monad was seen; now there were swarms of them, and all were of about the same size.

In Fig. 2, A (×500), some of these small masses are shown together with their contained bacteria; B (×375) shows a number of the small masses undergoing segmentation; while C (×700) shows one of these bodies more highly magnified, in which the segmentation into embryo Monads, still in a motionless condition, is almost complete.

In the course of the next day the Monads were found in prodigious numbers. They were spherical or ovoidal in shape, and provided with a single flagellum about twice the length of the body. Under a high power a nucleus could be distinctly seen, generally surrounded by a circle of very minute granules. In addition, two or three larger granules were to be seen—one of them, larger and more highly refractive than the others, being often present in the posterior half of the body of the organism, and there showing faint oscillations. Numbers of the Monads that were aggregated between three small contiguous air bubbles are shown in Fig. 2, D (×125), as they appeared under a low power of the microscope. Many of them were in active movement and are not shown, but those that were stationary were photographed by a very brief exposure. I found it impossible to photograph these particular Monads under a high power because they were mixed up with active bacteria, and were themselves very delicate in texture. The movements of these bacteria could not be arrested except by a comparatively strong osmic acid solution, or by exposure to the vapour of a 1 per cent. solution for more than half a minute, and in either case the result was to make the Monads almost invisible, if it did not cause their complete diffluence.

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[1] "Studies in Heterogenesis," p. 87 (1904).

[1] "Studies in Heterogenesis," pp. 69-73, Figs. 53-55.

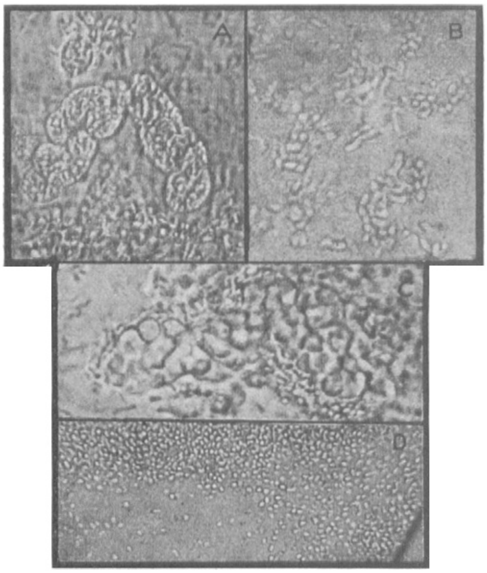

FIG. 2.—A, Small Zooglœa masses from the hay infusion (×500); B, Other of these masses undergoing segmentation (×575); C, One such mass the segmentation of which is nearly complete (×700); D, Monads derived from products of segmentation (×125).

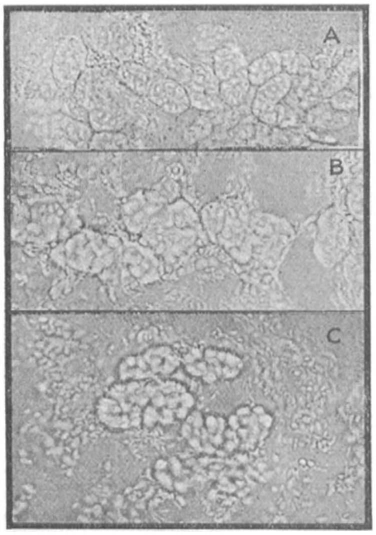

FIG. 3.—A, Portion of pellicle taken from the pot (×500); B, Small Zooglœa masses about to segment (×500); C, Small Zooglœa masses which have undergone complete segmentation (×500).

B. The closed pot was not opened until the end of the fifth day, and I then found the surface of the infusion covered with a very thin, scarcely perceptible film of bacteria, which on microscopical examination was seen to be densely crowded with very minute Zooglœa masses such as are shown in Fig. 3, A (×500). Not a single Monad was to be seen, but many of the masses were found to be about to segment as in B, or actually segmenting as in C, into a number of motionless spherical corpuscles.

During six subsequent days I uncovered the pot for a moment to take up on the tip of a sterilised scalpel a portion of the scum for examination, and on each occasion found the minute Zooglœa masses presenting similar characters, except that day by day a rather larger number of them showed evidences of segmentation, though not a single active Monad was to be seen.

The Zooglœa masses formed in the dark, and in a comparatively airless pot, were not only different in character from those formed in the open vessel, but it would seem that their process of change was slower and was in part arrested by the opening of the pot, since after eleven days there was still not a single active Monad to be seen, though in the open vessel swarms of them were found during the fourth day.[1] This arrest of the process of change recalls the similar arrest which was always found to occur when the pot was opened in which Hydatina eggs were being transformed into ciliated Infusoria of the genus Otostoma.[2]

It so happened that on the very day that I first observed the segmentation of the small Zooglœa masses in A I had on my work-table under a bell-jar a small petri dish in which a tuft of dead lichen had been soaking for a few days in distilled water. There was a very thin scum here and there on the surface of this water, and on examining a portion of it I was surprised to find that it also was crowded with small Zooglœa masses, many of which were apparently in different stages of segmentation into Monads, though the majority of them showed no signs of segmentation. Being busy with what seemed at the time to be the more important A infusion, I did not examine this new scum again until after the expiration of two days and then I found crowds of active Monads, and all the Zooglœa masses now in different stages of segmentation such as are shown in Fig. 4, A (×500). The only portion of an unaltered mass that I could find is seen on the left hand side of this figure, contiguous to the black speck. In the two days all the small Zooglœa masses had either

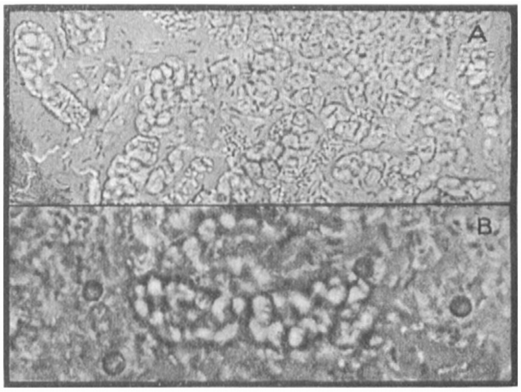

FIG. 4.—A, Minute Zooglœa masses in various stages of change (×500); B One of these masses in which segmentation has been nearly completed (×700).

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[1] Examinations of the scum taken from the pot have since been made at intervals during another week, and still, up to the eighteenth day, not a single Monad has been met with, though very many of the small Zooglœa masses have been found segmenting into pale brown Fungus-germs. But nine days ago (in order to test the question whether the *premature* opening of the pot had caused an arrest of the formation of Monads) I made another similar infusion from the same hay, and placed some of it in another small half-ounce pot, which was opened for the first time to-day. In the first portion of the scum obtained from this second pot I found swarms of active Monads, and also heaps of the small brown Fungus-germs resulting from the segmentation of other of the Zooglœa masses.—*November* 14.

[2] "Studies in Heterogenesis," pp. 49-51, and xiv.

become converted into Monads or altered in a more or less irregular manner. I attempted to stain some of the masses with a dilute solution of gentian violet. One of these, in which segmentation is pretty complete, is shown in B (×700), while the scattered products of another mass are shown in Fig. 5, A (×900), after they had been lightly stained with Westphall's mastzellen fluid. In this embryonic condition the future Monads are seen as spherical nucleated cells, either single or in pairs. Some of the Monads which were found a few days later in a motionless, resting condition, are shown in B (×700).

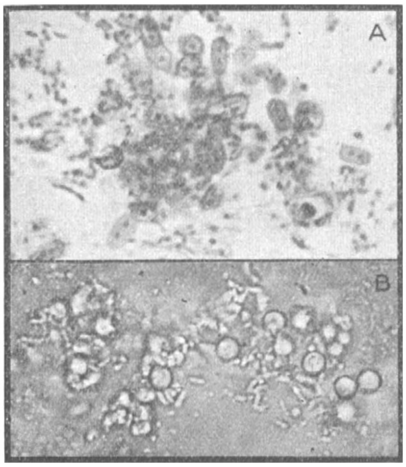

FIG. 5.—A, Products of segmentation stained, and appearing as minute spherical nucleated cells (×900); B, Monads in a resting stage (×700).

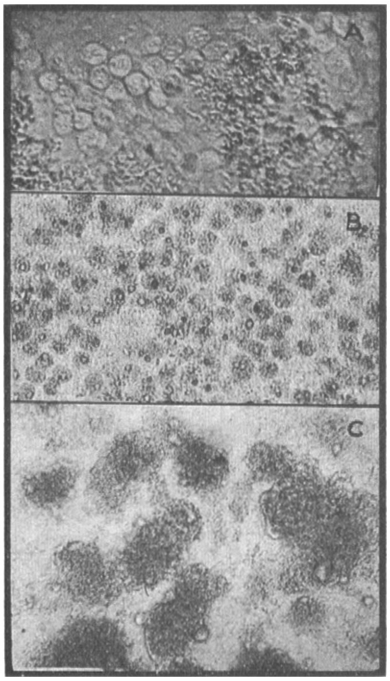

FIG. 6.—A, Monads developed from *Zooglœa* masses in a hay infusion (×500); B, Amœbæ stained with logwood, from an egg and water emulsion (×200); C, Amœbæ originating in the scum from an egg and water emulsion (×125).

On other occasions I had been a little more successful in photographing Monads produced from Zooglœa areas in a hay infusion. Thus Fig. 6, A (× 500), shows some such Monads, found on the third day, which had been developed from discrete corpuscles, and which were rendered motionless by a very weak osmic acid solution. These discrete corpuscles, as well as the motionless corpuscles derived from the segmentation of Zooglœa masses, sometimes become converted into Amœbæ rather than into Monads. What the conditions are that favour this particular change I have been unable to ascertain, though I know that in rare cases swarms of minute Amœbæ rather than Monads appear in this way in hay infusions. The production of swarms of minute Amœbæ is, however, the rule in the pellicle that forms on an emulsion made by pouring about eight ounces of water on a teaspoonful of mixed white and yolk of egg. Such Amœbæ, slightly stained with logwood, are shown in Fig. 6, B (×200), taken from a pellicle on the seventeenth day, while in C (×125) they are seen, as I believe, originating in another egg and water emulsion on the eighteenth day, in the midst of irregular clumps of bacteria. These aggregates of bacteria had been noticed for several days, but when first observed not a single Amœba had, up to this time, been seen either in them or in the surrounding fluid. Then there were appearances as though changes were taking place within the aggregates, followed in two or three days by the presence of swarms of minute sluggish Amœbæ around, and issuing from, the bacterial aggregates, as shown in the figure under a low magnification.

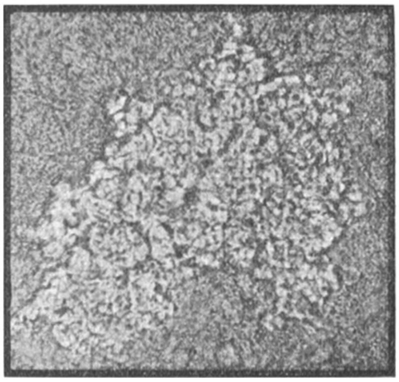

FIG. 7.—A Zooglœa mass undergoing change (×375).

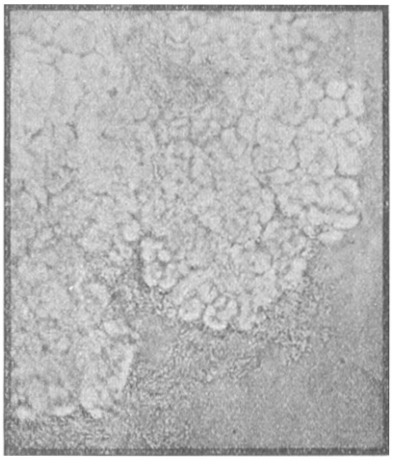

FIG. 8.—Portion of a Zooglœa mass about to segment (×500).

In reference to the occurrence of these swarms of minute Amœbæ, I may say that I have never seen one of them multiply by fission, and certainly their vast numbers are not to be accounted for in this way. I make these remarks concerning Amœbæ without pretending that what I have here said in regard to them is quite conclusive, or in any way comparable to the convincing evidence above adduced concerning the heterogenetic origin of Monads from the transformation of Zooglœa masses—a transformation in which we have vegetal organisms giving rise to animal organisms of a totally different kind, though between these two forms of life no relation of kinship has ever been admitted, or even suspected, by the great majority of biologists.

Origin of Fungus-germs from Masses of Zoogloea.

It has seemed to me, as I have said, impossible to say from the mere microscopical characters of the masses of Zooglœa whether they are likely to yield Monads or Fungus-germs. It will be observed, however, that in the three cases to which I have just referred the masses giving rise to embryo Monads have all been small, and that they have tended to go through their metamorphoses with some rapidity.

It is certain, however, that the great majority of the larger Zooglœa masses tend rather to produce Fungus-germs of one or other kind, and to go through their changes at a slower rate. These statements may be illustrated by a record of the changes taking place in the larger Zooglœa masses that were found in great abundance in the pellicle forming on infusion A. These larger masses of Zooglœa, and also all the later changes which I am now about to describe, were, however, wholly absent from the pellicle on infusion B, up to the eleventh day.[1]

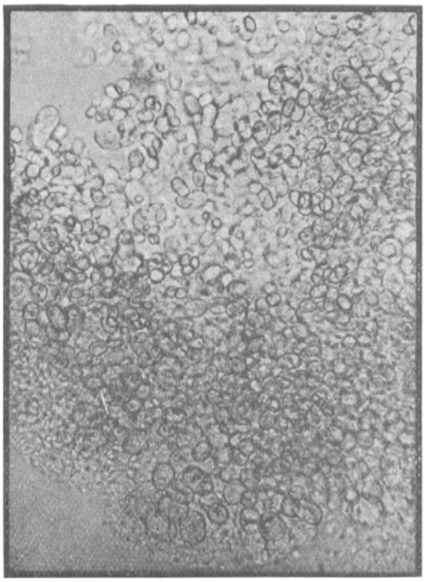

FIG. 9.—Development of small brown Fungus-germs from a mass of Zooglœa (×500).

Where the changes occur to which I would now direct attention the Zooglœa masses gradually become larger and much more refractive, while they also stain much more deeply with logwood, gentian violet, or other of the aniline dyes. At the same time the constituent bacteria, which are so very distinct in the early stages, seem to become enlarged and gradually more or less hidden as the molecular changes taking place in the mass increase. One of these aggregates in this refractive, glistening stage, which was found and photographed on the fifth day, is shown in Fig. 7 (×375).

The next stage of change is revealed by distinct indications of segmentation beginning to show themselves through the mass, such as may be seen in Fig. 8 (×500), which represents a portion of a large Zooglœa mass that was found on the sixth day. This condition may persist for several days, but occasionally further changes occur rapidly, as may be seen by Fig. 9 (×500), showing a portion of another large Zooglœa mass found on the seventh day, in which minute ovoid germs of different sizes are separating from the mass, and at the same time assuming a brown colour. This change was proceeding more rapidly at the edge of the mass; but further in, as may be seen in the upper portion of the figure, the mass shows more of the appearance to be seen in Fig. 8. Although the germs seem to separate from the metamorphosed Zooglœa mass as bodies of varying size, I think there can be no doubt that some of the separate units subsequently increase distinctly in size—though whether they undergo segmentation is not so clear. On the following day numerous heaps of brown Fungus-germs were found derived from these Zooglœa masses, forming clusters so thick and dense that their constituents could only be shown by pressing upon the cover glass firmly and thus breaking up the masses of germs. Portions of such a broken up mass are represented in Fig. 11, A (×500).

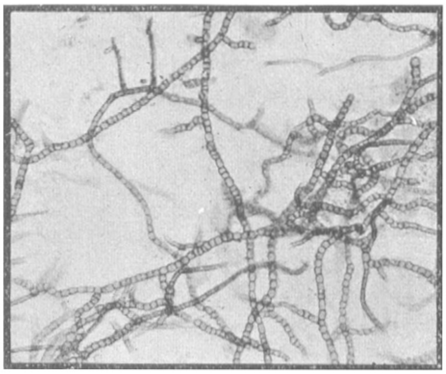

FIG. 10.—A portion of the brown mycelium (×125).

As a rule, these bodies show little tendency to germinate, but occasionally they do so, and two or three masses of mycelium to which they had given rise (also of a brown colour) were found on the eighth day. One of them had sent a hypha above the surface, and there produced a great number of ovoid acrospores having a bluish-black appearance. Some of the mycelium is shown in Fig. 10 (×125), while the acrospores are represented in Fig. 11, B (×500)

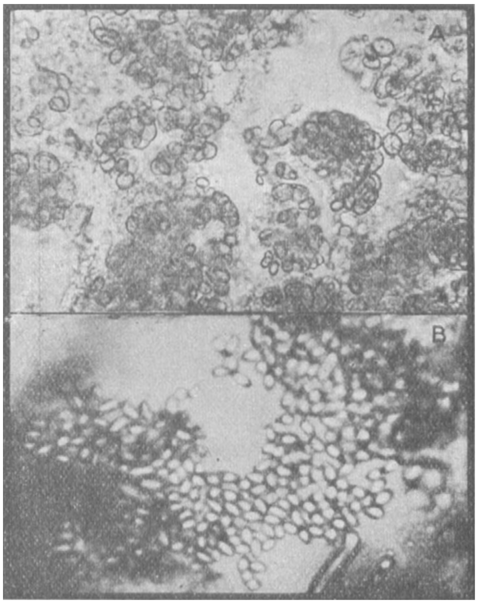

FIG. 11.—A, Heterogenetic Fungus-germs (×500); B, Acrospores produced from the mycelium (×500).

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[1] See note on p. 78.

It will be noted that the acrospores are comparatively uniform in size, and are wholly different from the extremely variable brown Fungus-germs produced from the Zoogl&oelig;a masses.

What has just been illustrated is only one of the ways in which Fungus-germs are produced in the pellicle from Zooglœa masses. Anyone working at this subject will have no difficulty in recognising many other modes in which they originate. Sometimes the germs separate from the Zooglœa masses as colourless units, and then take on an almost black colour before they begin to germinate, as in the specimen shown in Fig. 12, which was taken on the twelfth day from another pellicle on a hay infusion.

I have frequently found that these heterogenetic Fungus-germs are small ovoid bodies with one, or sometimes two, nuclear particles such as may be seen in this case, and also in some of the small brown units shown in Fig. 9. It is interesting, moreover, to find that the immediate products of segmentation which are about to develop into flagellate Monads present, except for their spherical shape, very similar characters, as may be seen by reference to Fig. 5, A.

It seems to me impossible to doubt that we have in the processes which I have just described definite instances of heterogenesis. The fact of the individualisation and the segmentation of these Zooglœa masses cannot be denied. It is plain, indeed, that from such aggregates of bacteria, by common consent regarded as belonging to the vegetal kingdom, we have the production of typical animal organisms, and that, as I have said, no kinship between bacteria and flagellate Monads has ever been recognised, or even suspected, by the great majority of biologists; and, though it cannot be said that there is the same lack of kinship between bacteria and Moulds, it can certainly be said that the majority of biologists have never suspected any such relation between these two forms of life as that which has now been made known.

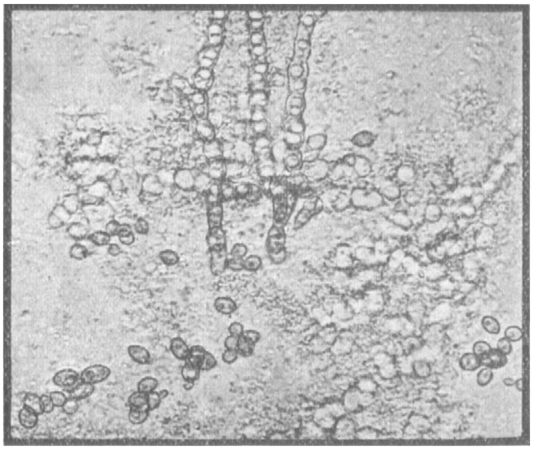

FIG. 12.—Heterogenetic Fungus germs becoming black and germinating (×500).

I care little what names may be given to the bacteria, though I am certain that many different varieties are prone to form zoogl&oelig;al aggregates, and to go through one or other variety of such changes as have just been described. Being much interested with these processes that go on in nature, and under more or less natural conditions, I have been familiar with such phenomena for more than a generation[1]; but although they were made known so long ago I am not aware that any bacteriologist in Europe, America or elsewhere has ever repeated my observations. Bacteriologists to whom I have personally mentioned the subject have, with only one exception, shown not the least desire to examine specimens or to follow up the inquiry. They seem wedded to their strict laboratory methods, and seemingly prefer to have dealings with nothing but pure cultures and sterilised media. I do not deny for a moment the enormous increase of knowledge, and the benefit which has accrued to the human race, from their studies, but should like to see a little more toleration displayed for those who prefer to work in a different way, and strive to find out what goes on under more natural conditions—undeterred by the much talked of but much over-rated risk of "infection." Assuredly, in the future, much of what is now ascribed to "infection" will be differently regarded as the "origin of species" by heterogenesis becomes more and more known.

If such processes as have just been described are continually going on in nature, but are not to be met with in the laboratories of bacteriologists, it should make us hesitate to repudiate a natural origin of living matter at the present day simply because undoubted proof of its occurrence cannot be produced by laboratory experiments. If it occurred in the past the law of Continuity would lead us to expect that it has been continually occurring ever since, and, as I said in my letter of November 10, "if the origin of living matter takes place by the generation in suitable fluids of the minutest particles gradually appearing from the region of the invisible, such a process may be occurring everywhere in nature's laboratories, though altogether beyond the ken of man."

H. CHARLTON BASTIAN.

The Temperature of Meteorites.

DURING the early part of the year 1901, when I was on the staff of the Elswick Works, it occurred to me that it would be useful and interesting if a connection could be made between the conditions of the flight of artillery shells and of meteorites. Later in the same year I made a preliminary mathematical investigation into the matter, and as a result a paper on the temperature of meteorites was sent in as an essay to compete for the Smith prizes at Cambridge. It was distinguished from other essays sent up in not receiving a prize.

It has since remained a strong wish on my part some day to work up the subject into a form fit for presentation to a scientific society, but the pressure of other matters has prevented this. In order, therefore, to preserve at least its outlines, I give here a brief exposition of the premises, the procedure, and the conclusions of the essay.

Ordinary ballistic tables contain a wealth of information as to the retardation experienced by projectiles of all sizes and of one general shape. The shape of the shell is well known. If the same rules can be made to fit the motion of meteorites it is clear that the velocity at any time can be obtained, and thence the loss of energy due to the obstruction caused by the air. This energy reappears as heat, sound, electrical energy, chemical energy, &c. Of these by far the most important is heat. Thus the conditions under which a meteorite "heats up" can be ascertained, and if it be assumed that all the energy is so spent, it is obvious that a superior limit to the resulting temperature may be obtained. One further point should, however, be mentioned—a meteor which reaches the earth is called a "meteorite," and the velocity necessary for this is such that the time of passage through the material part of the earth's atmosphere is so short, say five seconds, that chemical burning will not, in general, introduce any sensible error. Such error as might be introduced would be of the opposite sense to radiation losses, themselves small for much the same reason.

Meteorites may be of almost any shape. I have only considered the shell shape, as it is the only one the flight of which has been thoroughly investigated by exhaustive experiment.

According to Ingall's "Exterior Ballistics," the law of the resistance of the air is a function of the velocity which, for velocities above 1380 feet per second, is the velocity squared. For meteoric problems, velocities less than this are unimportant. Whether this simple law would hold good for velocities of, say, 20 miles a second, or even the 7 miles a second which the earth can impose, is not known, but for lack of a better it has been necessary to employ it.

The next difficulty, and of difficulties there is no small number, lies in the varying density of the air. A few thousand feet is the upward limit of ordinary projectiles. Even for howitzer shell the correction for rarefaction is so slight that the simplest kind of correction is enough. For

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[1] See *Proceedings* of the Royal Society, 1872, vol. xx. p. 239.